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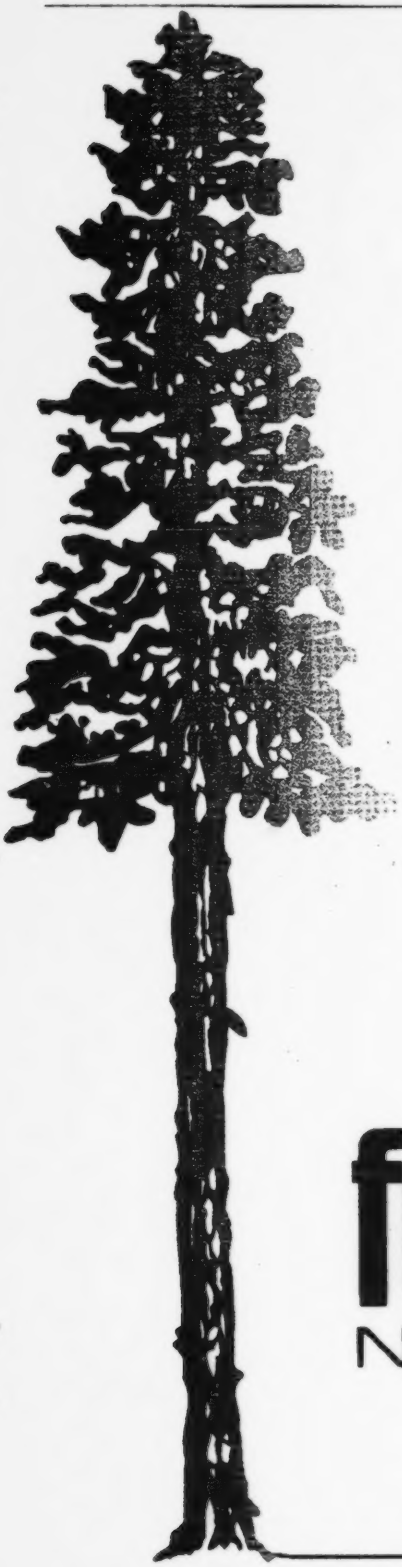

Armillaria Root Disease Management Guidelines For the Nelson Forest Region

Don Norris, John McLaughlin and Mike Curran

Technical Report TR - 014

forest sciences

NELSON FOREST REGION

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Table of Contents

1.0 INTRODUCTION 1

1.1 Statement of Purpose 1

1.2 Three Recognized "Needs" 1
1.21 Risk Assessment 2
1.22 Constraints Due To Site Factors 2
1.23 Treatment Options and Probable Outcomes 3

2.0 The Risk Assessment Matrix 3
2.01 Site Factors 4
2.02 Host Factors 4
2.03 Inoculum Potential 5
2.04 Disease Factors 6
2.05 Using The Risk Assessment Matrix 7

2.1 Treatment Recommendations by Risk Levels 9
2.11 Likely Outcomes and Probable Impacts 9

2.2 Silviculture Prescriptions: 10
2.21 Armillaria Risk Assessment Matrix for Silviculture Prescriptions 10
2.22 Soil Sensitivity Constraints on Inoculum Reduction Treatments 12
2.23 Site Characteristics and Constraints Checklist For Mechanical Treatments 14
2.24 Treatment Decision Tools: Armillaria Risk Vs Forest Floor Displacement Hazard 15
2.25 General Description of Treatments 17
2.26 Stump and Coarse Woody Debris Management During Root Removal 18
2.27 Soil Disturbance Associated With Root Removal Treatments 18

3.0 NOMOGRAPHS 18

4.0 STAND MANAGEMENT PRESCRIPTIONS 23

List of Appendices

Appendix I: Discussion of Risk Factors in the Risk Assessment Matrix 26

Appendix II: Discussion of The Role of Armillaria Root Disease Surveys..... 28

Appendix III: Armillaria Risk vs. Treatment Risk: Interpretation of Likely Outcomes and Probable Impacts..... 29

Appendix IV: Application Examples of Armillaria Risk Assessment Matrix..... 37

List of Tables

Table 1: Armillaria Risk Assessment Matrix For Silviculture Prescriptions 11

Table 2: Site Characteristics and Constraints Checklist for Mechanical Treatments12..... 14

Table 3: Armillaria Risk Assessment Matrix For Stand Management Prescriptions20..... 24

Table A I - 1 Armillaria Susceptibility Risk by BEC and Tree Species Groups 26

Table A I - 2 Host Susceptibility to Armillaria in the Nelson Forest Region 27

List of Figures

Figure 1: Site Characteristics And Constraints Flow Chart..... 15

Figure 2: Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region - ICH Wet Belt..... 19

Figure 3: Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region - PP, IDF, MS, and ICH (dw, xh and mk) Biogeoclimatic Zones..... 21

Figure 4: Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region: ESSF Biogeoclimatic Zone..... 22

1.0 INTRODUCTION

The Provincial Root Disease Management Guidebook, (Province of BC, 1995), hereafter referred to as RDMG, provides a basic framework for root disease management in British Columbia. This report is intended to give more specific recommendations for Armillaria Root Disease (DRA) management in the Nelson Forest Region. These recommendations are a refinement of the general guidelines presented in the provincial guidebook and have been reviewed in the office and the field. The recommendations expand and build upon steps 4 and 5 of the Root Disease Evaluation Process in the RDMG and are based on research, site conditions, and observations in the Nelson Forest Region.

1.1 Statement of Purpose

The aim of these guidelines are to provide managers, planners and prescription writers with information and procedures by which they may make informed management decisions rather than to simply prescribe certain "cookbook" courses of action.

It is anticipated that this report will be used as an aid in developing Forest Development Plans[1], and in turn Silviculture and Stand Management Prescriptions, with the principal aim of growing stands that will produce high timber yields. References to the impact of Armillaria root disease and evaluation of the "risks" associated with applying various silvicultural practices under different levels of disease will, therefore, reflect this goal, while still managing for other resources.

Managers and prescription writers who are striving to meet primary stand management objectives other than timber production (e.g., enhancing wildlife habitat, tree species mix) will also find the supplement useful. In some cases, Armillaria root disease itself may be seen as a tool for producing a desired stand structure (e.g., wildlife trees for cavity nesters and edge effect for mammals).

1.2 Three Recognized "Needs"

Armillaria risk by BEC Zone (revised and included as Table AI - 2 in Appendix I) and the Risk Matrix can be used to assist in constructing Forest Development Plans and integrating the Landscape level objectives into higher level plans.

Management of Armillaria root disease in the Nelson Forest Region will be facilitated by clarification of three key issues:

- stand-based risk assessment,
- constraints on treatment selection due to site characteristics, and

[1] Depending upon legislative changes.

- the nature and probable outcome of various treatments.

Field assessments can be done in the above order using specialized surveys or data collection can be combined with other surveys. We suggest that root disease be assessed first followed by a soil hazard assessment and then follow this guide to develop the prescription.

1.21 Stand Based Risk Assessment

Until now assessment of the risk of undesirable impacts by Armillaria root disease following harvesting has been based largely on detectable disease observed by various pre-harvest above-ground surveys. Although simple in concept and in execution, these methods fall short in recognizing variation in risk due to factors such as BEC zone, soil moisture, and disease expression.

Assessing the risk due to Armillaria root disease involves integrating risk factors - site, host, inoculum potential and disease at the broad level - and specific risk indicators (e.g., stand composition, soil moisture content, currently apparent aggressiveness of the pathogen, inoculum potential) in *a risk assessment matrix*. By evaluating the cumulative value of the risk factors the user will be able to identify the relative level of risk associated with various treatments and will be able to select treatments which will modify the risk.

Selection of a treatment is then based on the cumulative level of risk, availability of resources (e.g., funds, expertise, equipment), and management objectives, both at the landscape and stand level.

This approach allows flexibility in response to Armillaria root disease conditions but demands greater professional judgment in selecting a treatment option and justifying this choice in a forest development plan. Although more complicated than a risk assessment based solely on surveyed disease incidence, the risk assessment matrix approach recommended in this report recognizes that the amount of disease expression is not in itself an adequate measure of risk and that root disease management is not an exact science.

1.22 Constraints Due to Site Factors

Balanced against reduced tree growth due to Armillaria root disease are the losses which may result from soil disturbance caused by Intensive root disease treatments. Soil disturbance hazards must be considered when deciding what root disease treatment to choose. The most sensitive soil conditions are screened out from mechanical treatment options. If a site meets the soil sensitivity criteria, forest floor displacement hazard are then considered in the nomographs outlining potential treatment options. On borderline sites or on those sites where site preparation is

not a consideration, the "intensive deferred" treatment option (pop-up spacing) should be considered because less disturbance is created and this treatment leaves stumps and large roots in the soil for biodiversity.

1.23 Treatment Options and Probable Outcomes

When Armillaria root disease is detected on a site there are a number of options available to the manager in dealing with the assessed risk. In the Root Disease Management Guidebook these treatment options are referred to as "Minimal", "Alternate", and "Intensive" Treatments.

Briefly, the Minimal Treatment option is to choose conventional harvesting and regeneration strategies without restrictions, which is appropriate where the assessed risk is low. The Alternate Treatment option is appropriate when the assessed risk is moderate and the strategy is to prescribe species considered less susceptible to Armillaria root disease and to avoid partial cutting systems (unless clearcutting, patch clearcutting or group selection is not feasible). For high risk sites, Intensive Treatment options includes inoculum reduction through push-falling or stumping at the harvest stage. At the early stand management stage, intensive treatment includes pop-up spacing (either before or shortly after free growing), a treatment generally preferred from a soils perspective. Experimental treatments, such as biological control or fallow, can not be included until such time that they are proven effective and operationally feasible.

In Appendix III an attempt is made to predict the nature and probable outcome of various treatment options or types in the presence of high, moderate and low DRA risks. These predictions are offered to provide a framework for deciding which management objectives are achievable under a variety of conditions.

2.0 THE RISK ASSESSMENT MATRIX

In order to address the need for a more flexible, comprehensive risk assessment method for evaluating stands, a Risk Assessment Matrix has been devised. **The Risk Assessment Matrix is a conceptual key or problem analysis tool that supports the five-phase procedure for prescription development described in the Root Disease Management Guidebook.** Factors considered are grouped by site conditions, host tree species, current disease expression and the probable effects of previous silvicultural or harvesting treatments on inoculum potential.[2] Conditions associated with each factor will indicate a low, moderate, or high contribution to risk of negative impacts which could result from conventional strategies.

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[2] The term inoculum potential was defined by Garrett(1970) ,as "the energy of growth of a parasite available for infection of a host, at the surface of the host organ to be infected." Inoculum size, distance between the host and the inoculum, and the influence of the environment on the pathogen are the major determinants of inoculum potential

The Root Disease Management Guidebook describes several root disease survey methods. However, the Armillaria risk assessment matrix survey does not attempt to measure that which cannot be measured - the real amount of infection in the stand. Rather, it is used to gather the necessary quantitative (e.g., # of disease centres), qualitative (e.g., species/site suitability) and spatial (e.g., distribution of disease centres) that are visible to surveyors or prescribers. Therefore, any survey method that can be used to accurately and efficiently gather this data is appropriate. In some cases a walkthrough may be adequate whereas in others a systematic survey such as the line transect method may be necessary in order to provide spatial information about disease distribution.. In any case, all surveys are required to do is estimate whether the disease on site is High, Moderate or Low. The pseudo precision involved in reporting disease incidence in numeric values is avoided by using these broad categories (See Appendix II for a discussion of the problems associated with surveying for Armillaria root disease).

2.01 Site Factors

BEC zone - Certain BEC zones are considered higher risk for Armillaria than others (see Appendix I).

Soil Moisture Regime - Recent research[3] suggests an important influence of soil moisture on Armillaria presence and pathogenicity. Sites that are either very wet or very dry are less likely to be severely affected by Armillaria, while circum mesic conditions are ideal for Armillaria growth and pathogenic activity.

2.02 Host Factors

Species Mix and Age - All conifer species are considered susceptible until approximately 15-20 years of age. At that time, differences in susceptibility to infection and to subsequent mortality become apparent (for further discussion see Appendix I).

Species/Site Suitability - Trees that are adapted to the site conditions ("on-site") are usually better able to contend with Armillaria infections, often isolating them with callus tissue, while trees not well adapted to the site ("off-site") are often more seriously affected.

Off-site species can be identified by referring to the Land Management Handbook Number 20 (Bruamandl and Curran, 1992). Species not listed as primary or secondary[4] or species exhibiting symptoms of chronic foliage diseases and reduced

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[3] Cruickshank et al, 1997

[4] Tertiary species usually have an ecological limitation and thus have a high probability of being "off-site". White pine is a special case due to White pine blister rust. White pine from registered resistant stock may be used as a normal ecosystem component and removed from the "tertiary" listing.

leader growth, (especially Fd, Lw, Pl) are all indications that they may not be well suited to the site. Rapid growth rate is not a guarantee against Armillaria, especially in young plantations and especially when using improved genetic stock[5]. Rapidly-expanding root systems make contact with infective root material sooner than those of slower growing trees.

Species susceptibility - Tree species vary in their susceptibility to DRA infection. Differences in susceptibility start sometime after 15-20 years and is expressed in terms of either ease of infection or ease of mortality or both (see Appendix I). This component is built in to Species Mix within the risk assessment matrix.

2.03 Inoculum Potential

A principal consideration associated with any silvicultural treatment is the production of stumps. These stumps and associated root systems provide an abundant food base for Armillaria, resulting in heightened capacity to infect roots of host trees. The general rule is that small stumps result in lower inoculum potential and decompose more quickly than larger stumps. Some differences have been observed in species decay rates, but these need further quantification.

Previous disturbance history also affects the inoculum potential. Stumps created during harvesting create Armillaria food base levels generally unknown under natural conditions[6]. Armillaria is uniquely able to take advantage of these conditions.

Even with the smaller stumps in stands less than 20 years old, previous stand tending activities, such as brushing or stocking control, can create new stumps (food base) sooner than otherwise would have occurred. This can adversely effect stand development by contributing to inoculum load, increasing juvenile mortality and encourage unplanned shifts in the species profile.

If stumping or pushover logging was conducted, the risk from future Armillaria infection is reduced. Similarly, pop-up treatments reduce Armillaria risk for the remaining stand, through inoculum removal and breaking root contacts, thereby delaying subsequent infection until the trees are larger and better able resist the disease.

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[5] Preliminary evidence from the CFS Armillaria root disease research program indicates that fast growing trees may be inherently more susceptible.

[6] Stumps created during forest fires generally dry out sooner, and the associated stems are more susceptible to insect attack and underbark "contamination" from other fungal/bacterial infection. Most trees killed during forest fires are uprooted in succeeding years. All these factors tend to mitigate against but do not exclude DRA spread to the next generation. Stumps created by harvesting on the other hand can live for several years and can resist invasion and colonization by a variety of decay fungi, thereby maintaining a sterile environment for DRA spread. Harvesting seems to provide a headstart for DRA in comparison to root systems in trees killed by forest fires.

2.04 Disease Factors

Prior to discussing disease factors, it is essential to understand two concepts. There may be (and usually is) a significant difference between the number of symptomatic trees observed and the actual number of trees infected, but not yet exhibiting symptoms. This fact is relevant to the discussion of the value and role of surveys for measuring Armillaria root disease incidence in Appendix II.

The behaviour of the disease observed in the field is, in effect, a snapshot of the current dynamic interaction among hosts, pathogen and environment. Activities that disturb this relationship and increase inoculum potential which can lead to elevated disease activity (e.g. conventional spacing, commercial thinning).

Incidence (The proportion of the site exhibiting disease signs and symptoms.) - Disease may be detectable in few or many host trees, providing a measure of distribution and Armillaria virulence under current conditions. High, medium and low incidence levels are defined on page 7.

Distribution - The proportion of the site exhibiting disease and its distribution are significant factors. Disease may be detectable within definable centres or may be ubiquitous. Disease incidence may be high but restricted to only a portion of the site, allowing for stratification for operational purposes. Ubiquitous or diffuse distributions cannot be stratified.

Host Species found to be Symptomatic - Disease signs which are affecting resistant species indicates a more serious risk than that which is affecting only moderately susceptible or the most susceptible species.

Stand Layer Exhibiting Symptoms - The stand layers affected by Armillaria act as an indicator of Armillaria virulence *under current conditions*. If current virulence is low, only smaller/suppressed trees will be symptomatic whereas if virulence is high, all layers may exhibit symptoms of root disease.

Stage of Disease Activity - Sometimes only grey, DRA infected dead trees will be observed, indicating that there has been no recent mortality. In other cases there will be grey, red, and yellow trees, indicating that mortality is both recent and has been ongoing for a number of years. The presence of only "greys" may indicate that the trees are successfully compartmentalizing infections. However, successful compartmentalization will breakdown if these trees are killed by other organisms or abiotic events.

Pest Interaction - Some pests act independently of Armillaria while at the same time they can promote the root disease. Notable examples include white pine blister rust (DSB) and foliage diseases. Pw trees typically grow faster than other species and

develop large root systems. While the trees are alive they resist the fungus but when these trees are killed by DSB (or foliage disease), their root systems become high quality food bases from which Armillaria can spread to adjacent trees. Similarly, defoliating insects can have the same effect when they kill trees. Larch and Pl root systems can also grow quickly and if affected by foliage diseases or dwarf mistletoe (or in the case of Pl, other stem rusts), these species can more easily become infected and add to the inoculum load on site.

In contrast, other pests, notably bark beetles in endemic conditions, and in stands that are normally too young to show either Armillaria or Bark beetle attack, bark beetles often act as root disease indicators.

2.05 Using the Risk Assessment Matrix

In order to use the Matrix, information pertaining to the various host, site and disease factors is gathered through a survey of the block. The conditions relating to each of the factors are recorded and assigned to the low, medium or high risk levels.

You will note that the "Moderate" relative risk section of the Matrix actually allows representation of a range of conditions for some factors, from a low - moderate to a high - moderate level of risk.

The risk matrix represents a conceptual key that involves judgment on the part of the user and includes the following steps:

1) record the data requested under each risk factor. Most of this data will be required for other purposes in most site inspections for Silviculture or Stand Management prescriptions;

2) within the risk factor table, circle the condition within each risk factor that corresponds to your site, the bolded number (e.g., **(4)**) is the risk weight assigned to that category;

3) only one factor per row may be selected. Under some circumstances there may be a transitional situation: make two assessments using the two possible weightings. After summing the weights by rows, a choice can usually be made, modified by your or other's experience with these sites;

The relative risk points are summed (vertically) and indicate either a Low (-4 to 17 points), Moderate (18 to 30 points) or High (>30 points) overall risk. These are the risk points that would be associated with the selection of conventional strategies (stump left in ground). In cases where the sum is close to a class boundary (e.g., 26 or 32 risk points), the structure of the Matrix allows analysis and flexibility in deciding upon a treatment option.

By considering what factors have contributed most to the total risk sum, the user can better decide whether to select the treatment options related to a Moderate risk level (i.e., Alternate Treatments) or to be more cautious and select the treatments appropriate to a High risk level. The general rule should be to review which of the main factor groups were the more seriously rated. The order of the importance increases as you proceed down the table for the main groups (*individual factors within each group are not ranked*).

The features bolded under High Relative Risk in both Table 1 and 3 are believed to be of particular importance. Further, if the site has 3 or more of the highlighted (bolded) factors (ICH, Susceptible species, large, high and yellow/reds) but still obtained a risk score of 26, the site should be ranked as high. Alternatively, if the site factors and host factors were all high but all the others were low or low moderate, then a site with a 18 or 19 score should remain a low risk site. It is important to note that *if the disease factors are all low or all high, these factors should predominate when assessing the risk.*

Please note that under Species mix and Inoculum Potential, there is a possibility of counting a "negative" risk. Root removal and a species mix of three or more conifers, one of which is tolerant (Lw or Py), has the effect of reducing risk from high hazard Site and Host factors as much as those factors increase the risk.

Within Tables 1 and 3 below, under incidence:

High: Obvious disease conditions are defined as including one or more of the conditions:

* > 20% of the stand are in clearly defined centres
* > 10% of the crop trees are dead (gray or red) or infected (yellow)
* root disease attack is diffuse, but individual symptomatic trees can be observed every 20-30 m along traverse lines or in any given direction
* the largest trees in the stand are symptomatic of root disease attack
* attack is found on most of the individuals of one or more species groups
* with any of the above the overall health of the stand appears poor, crowns raggedy, diameters smaller than normal, poor growth rates even though large roots are not infected near the root collar;

or if an evaluation indicates that

* disease found on site is felt to represent a threat to one or more of the major stand objectives or objectives of higher level plans, or
* disease on site is felt to represent a forest fire hazard, public safety risk, a bark beetle outbreak risk, or a risk to stand survival prior to the next planned entry.

Low: means that disease conditions are defined as either;

* no symptomatic diseased trees are evident in the stand (i.e.,: none), or

* if disease is present, then it is being expressed in apparently insignificant amounts in a few scattered individuals (i.e.,: fewer than one tree per 100 m of traverse is symptomatic of root disease infection)[7] (i.e., scarce); and

Moderate means that the disease level is somewhere between high or low.

2.1 Treatment Recommendations by Risk Levels

The Risk Assessment Matrix assists the prescription writer to estimate the risk associated with applying conventional harvesting and regeneration methods in stands infected with Armillaria Root Disease. Identification of a **low**, **moderate** or **high risk level** directs the user to associated treatment options, referred to in the Root Disease Management Guidebook as **Minimal, Alternate** and **Intensive treatment levels,** respectively (see RDMGB pages 32-46 for descriptions of treatment options).

Minimal and Alternative Treatments are straight forward. However, in a Silviculture Prescription, the intensive treatments referred to usually mean inoculum removal via post harvest stumping or pushover logging. Another form of inoculum removal, the pop-up group of treatments (e.g., pop-up spacing) are referred to as intensive deferred **(Id).** Pop-up spacing can be prescribed for use before free growing under certain circumstances, especially where soil sensitivities are an important issue or where there is still some debate over the severity of the site sensitivity or the risk from DRA.

With regard to free growing assessments, the Armillaria Risk Assessment Matrix for Silviculture Prescriptions is to be used to assess free growing conditions in regenerating stands. Young stands that are of low risk can be approved for early free growing. Stands that are a high risk, should not be accepted as free growing unless the most intensive treatments possible for that site have been conducted according to the approved Silviculture Prescription and/or contractual obligations.

2.11 Likely Outcomes and Probable Impacts

In Appendix III, a table of Relative Armillaria Risk, subdivided by Treatment Types is matched to Treatment Descriptions, Likely Outcomes and an interpretation of Probable Impacts, based on the current knowledge of DRA. The objective of this series of tables is to present to prescribing foresters a series of likely outcomes if they choose to mix and match different relative Armillaria risks with different treatment options to achieve a variety management objectives. The probable impacts that are provided could be used to obtain a subjective estimate of "cost" and chance of success of any given management objective (including non-timber objectives) given certain risks and treatment actions. These interpretive tables are based on empirical

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[7] Obviously where there are a few scattered or scarce infected individuals present there will be a slight elevation of risk and this is reflected in the table. Our understanding of root disease is not yet at a level where hard and fixed thresholds can be defined.

observations and professional judgment of the pathologist and field practitioners and therefore are not presented as definitive results but rather as a guide to assist prescription developers

2.2 Silviculture Prescriptions:

2.21 Armillaria Risk Assessment Matrix for Silviculture Prescriptions

Table 1 is to be used in developing Silviculture Prescriptions and assessing free growing stands. When using this risk matrix to assess early free growing, if the site was **not** stumped or pushover logged and the risk points are in excess of 23, then do **not** approve early free growing applications. Applications for free growing near the deadline that exceed 23 points should be examined closely to determine where the risk points are originating. If the Disease Factors are low, then approval may be appropriate but if they are high then some form of treatment would be required, unless the disease was recognized and the licensee has done everything proposed in their approved SP properly, the District Manager can alleviate their Free Growing responsibilities. ***Otherwise, stands of moderate risk should only be accepted for free growing only if they score less than 23 points, are at latest free growing age and meet all other requirements.***

Under Host Factors in Table 1, only use the negative risk factor of **(-3)** if there are two conifers on site, each of which comprise > 20% in the silviculture label and at least one of them is tolerant of Armillaria root disease. This factor is **only** to be used in Free Growing assessments and **not** merchantable stands. This recognizes the possibility that mixed stands may be more able to resist Armillaria.

Under Inoculum Potential in Table 1, use the **(-5)** risk points **only** in free growing surveys when this treatment was actually performed. Do **not** use this risk rating when assessing merchantable stands.

While it is not necessary to include the full risk assessment table with Silviculture Prescriptions, it would be advisable to include the point totals for each of the four major risk factors (site, host, inoculum potential and disease).

Table 1 Armillaria Risk Assessment Matrix for Silviculture Prescriptions

RISK FACTORS[8]	RELATIVE RISK			
	Low	Moderate		High
Site Factors	+2 to +8 possible contributing points			
BEC Zone	PP (1)	IDF (2)	IDF (transitional), ESSF (>200m of elevation from the ICH) (3)	ICH, MS, ESSF,(<200m of elevation from the ICH (5)
Soil Moisture Regime	*Very Dry* (~ 120 days moisture deficit during growing season) in PP or IDF (i.e., subxeric or drier) or *Very Wet*, (excessive moisture during the growing season) in ICH, MS, or ESSF (i.e., hygric or wetter) (1)			All Others (3)
Host Factors	minus 2 to +13 possible contributing points			
Species mix (leading species[9] only)	Py, Lw & Ep, At, Ac, if < 40 years (1)	Py, Lw &/or Pl, S, Hw, Cw, Pw (2)	Py, Lw &/or Pl, S, Hw, Cw ,Pw with significant (> 20%) levels of Fd/ B (3)	**Fd, B and (if roots are older than 40 Years)** Ep, At, Ac (5)
For FG[10] only Species Mix (leading)	(-3) if >2 conifers are on site & 1 is Lw, Py or Pw on moist ICH sites			
Species age	< 140 years (1)	> 140 - < 250 years (3)	Within limits of low or moderate risk but starting to show signs of decadence (4)	>100 Years Fd or B or >250 - all decadent stands of conifer species (5)
Species/Site suitability	"on site" as identified in Land Management Handbook # 20 (0)			Off - site (ecological limits apply) (3)
Inoculum Potential	minus 5 to +5 possible contributing points			
Previous Management e.g. previous logging	none (0)	Clear cut, seed tree, group selection (3)		Single tree selection (5)
For FG only	(-5) if 12 if pushover log or stumped[11]			
Disease Factors	0 to +30 possible contributing points			
Incidence	none (0) scarce (1)	(2) ⇐ approaching low	approaching high ⇒ (3)	**High** (5)
Distribution	none (0) scarce (1)	(2) ⇐discrete centres	discrete centres ⇒ (3)	diffuse (ubiquitous) (5)
Host species (being attacked)	none (0), if scarce attack/ any species (1)	susceptible only (2)	susceptible & moderate (3)	all including resistant[13] (5)
Stand layer (being attacked)	none (0) layer 4 (1)	layer 4 's and 3's (2)		layer 1, 2, and 3's (5)
Disease activity	none (0); if some greys (1)	if greys and reds (2)		**yellow - greens/ yellows/reds** (5)
Pest Interaction	none (0)	if any DFx[14], DMx or DSx (but no DSB IBx) (3)		yes (i.e. DSB or IBx) (5)
Point Totals	(-5) to +17	18 to 30		> 30

[8] Risk is defined as the probability of undesirable impacts resulting from conventional types of forest management treatments.

[9] By definition only those species ≥ 20%; bracketed species do not count.

[10] Species composition is based on silviculture label and both conifers comprise > 20% of the silviculture label.

[11] Stumping or pushover logging reduces risk as much as yellow/red disease activity increases risk.

[12] Use only in free growing surveys when this treatment has actually been performed; not as a future activity

[13] If DRA is affecting "resistant" species, then the risk from DRA is thought to be higher.

[14] DF = disease foliage and the "x" refers to any species affecting trees; DM = dwarf mistletoe; DS = stem diseases; IB = bark beetle.

If a harvesting stand entry is planned and the indices derived from either of the Armillaria Risk Assessment Matrices indicate a need for root removal, then the next step is to ascertain the soil sensitivities present on the specific site (as described below in the section titled "Soil Sensitivity Constraints on Inoculum Reduction Treatments"). If the soil sensitivity criteria are met, then use the indices derived from the appropriate risk matrix (SP or SMP) and estimated forest floor displacement hazard to enter the Nomographs presented below.

2.22 Soil Sensitivity Constraints on Inoculum Reduction Treatments

Stumping and push-over harvesting are the recommended methods for inoculum reduction. Stumping removes stumps and large roots in a separate step following harvest while push-over harvesting simultaneously incorporates stump and root removal with the falling operation. Both of these methods work well at reducing inoculum loads. However, there are some constraints arising from the use of heavy machinery which may cause unacceptable soil disturbance on some sites. Because the productivity of a site can be adversely affected by excessive detrimental soil disturbance (e.g., soil compaction, erosion, mass wasting, soil disturbance) as well as by root disease, the possible soil disturbance losses must be weighed against anticipated root disease losses when considering intensive disease treatments.

In setting recommended disturbance limits, the FPC Soil Conservation Guidebook focuses on the cumulative effects of displacement. In any case, any soil disturbance has the potential to have serious off-site impacts (e.g., runoff, sedimentation, water and visual quality). The objective here is to optimize trade-offs between both major sources of potential impacts. Table 2 (an expanded version of Table 7 of the RDMGB 1995) is a guide to assessing the soil sensitivity of a site when considering mechanical treatments.[15] :

Generally, from a soils perspective, pop-up treatments are thought to be more desirable than stumping, which in turn is preferred over pushover logging. However, in some instances, root removal treatments can provide site preparation without the need for a future mechanical treatment, in which case the order of preference could be reversed. This is reflected in the nomographs along the Forest Floor Displacement axis. A series of nomographs for a number BEC zones (figure 1 - 3) have been developed as aids in judging the relative risks of forest floor displacement and Armillaria root disease and the interaction of these risks on the selection of treatment options[16].

Forest Floor Displacement Hazard is a fundamental consideration in developing prescriptions, particularly in root disease treatments. Forest Floor Displacement provides an index of the relative importance of surface organic matter, including roots. As well, Forest Floor Displacement provides an index of the likelihood of getting a site

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[15] Reference: *Hazard Assessment Keys for Evaluating Sited Sensitivity to Soil-degrading Processes--Interior sites*, 1995, FPC Guidebook, Province of B.C.

[16] The thresholds delineated in the nomographs were derived through consultation between the root disease specialist and the soil specialist and represent their best judgment at this time

preparation effect (low and moderate FFDH typically occur on richer sites with thicker forest floors and/or more competing vegetation).

Mass Wasting Hazard is an important consideration because root removal treatments at or around harvesting removes roots that provide soil strength and can interrupt natural water seepage patterns during spring runoff that could lead to concentrating water in some sensitive sites.

In making decisions regarding the treatment of root disease, the prescriber must make a determination of which factors are likely the most limiting to achieving objectives both in the long and short - term.

2.23 Site Characteristics and Constraints Checklist for Mechanical Treatments

Table 2 below outlines the site characteristics and constraints involved in using mechanical treatments.

Table 2 Site Characteristics and Constraints Checklist for Mechanical Treatments

Evaluation Criteria [a]	Are Each Criteria Being Met? (on the site in question)		
	For Stumping or Push Over is		**For Pop-up Space is**
Mass Wasting Hazard Low or Moderate	Yes / No	≤ High (not with clayey soil texture)	Yes / No
Soil Erosion Hazard is ≤ 26 points	Yes / No	≤ High (but no continuous trails or gouges into mineral soil)	Yes / No
Soil Compaction Hazard Low or Moderate	Yes / No	≤ High (only if non cohesive soils [b])	Yes / No
Soil Displacement Hazard for:			
Unfavourable Subsoils	> 45 cm	> 30 cm	Yes / No
depth to seepage	> 60 cm	> 35 cm	Yes / No
Slopes	< 30 %	< 30 %	Yes / No
minor pitches[c]	none or few (see foot note 16)	< 45 % (on snow or self leveling machine)	Yes / No

a From Hazard Assessment Keys for Evaluating Site Sensitivity to Soil Degrading Processes Guidebook. If one of the site evaluation criteria is exceeded, consult the regional pedologist or pathologist for possible prescription recommendations. (note: to exceed any one of these criteria[17], a history of good performance by the proposed operator must documented.) If two or more criteria are exceeded, then in most cases do not use mechanical treatment for root disease control; if it is considered a benchmark issue for your District, consult with the Regional Pedologist to discuss the possibility of a limited operational trial.

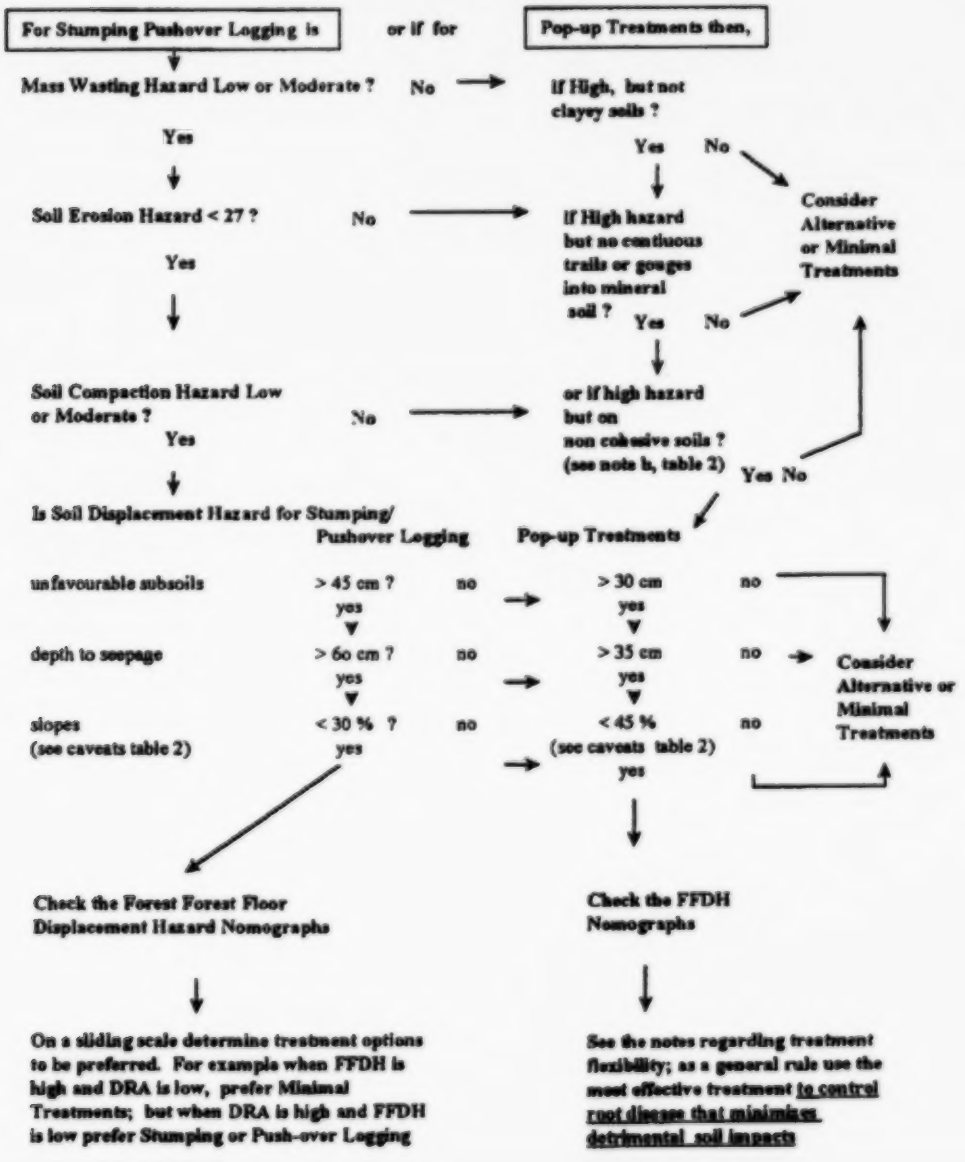
b You cannot make a "worm" 8 mm or smaller. An example of a high compaction hazard on non cohesive soils would occur on loam, SiL and Si textured soils with a low clay content (i.e., non-sticky or just slightly sticky).

c Slope pitches should be less than 50 m in length. On compressible snow during pop-up spacing, somewhat steeper pitches may be conducted if machine or soil stability are not compromised (see foot note 16).

[17] Operator skill is the most important factor in mechanical treatments. A good operator can work on more difficult terrain than specified and still keep within disturbance limits. Hence some risk management can be considered with operators who have demonstrated their skill in previous work.

Figure 1 places the Site Characteristics and Constraints Checklist for Mechanical Treatments in a flow chart format for easier use.

Figure 1 Site Characteristics and Constraints Flow Chart


For Stumping Pushover Logging is
or if for
Pop-up Treatments then,
Mass Wasting Hazard Low or Moderate ?
No
If High, but not clayey soils ?
Yes
Yes
No
Soil Erosion Hazard < 27 ?
No
If High hazard but no continuous trails or gouges into mineral soil ?
Yes
No
Consider Alternative or Minimal Treatments
Yes
Soil Compaction Hazard Low or Moderate ?
No
or if high hazard but on non cohesive soils ? (see note h, table 2)
Yes No
Yes
Is Soil Displacement Hazard for Stumping/ Pushover Logging
Pop-up Treatments
unfavourable subsoils
> 45 cm ?
no
yes
> 30 cm
no
yes
depth to seepage
> 60 cm ?
no
yes
> 35 cm
no
yes
Consider Alternative or Minimal Treatments
slopes (see caveats table 2)
< 30 % ?
no
yes
< 45 % (see caveats table 2)
no
yes
Check the Forest Forest Floor Displacement Hazard Nomographs
Check the FFDH Nomographs
On a sliding scale determine treatment options to be preferred. For example when FFDH is high and DRA is low, prefer Minimal Treatments; but when DRA is high and FFDH is low prefer Stumping or Push-over Logging
See the notes regarding treatment flexibility; as a general rule use the most effective treatment to control root disease that minimizes detrimental soil impacts

2.24 Treatment Decision Tools: Armillaria Risk vs. Forest Floor Displacement Hazard Nomographs

If the site characteristics and constraints checklist criteria are met, then use the nomograph decision tools to develop silviculture treatment prescriptions for a given Armillaria risk level and forest floor displacement hazard. If the criteria are not met, then use the Alternative treatment options.

The zones of the nomographs between the treatment thresholds indicate, in general terms, the most suitable prescription for DRA control for a given Forest Floor Displacement Hazard (FFDH). They should be considered guides (and not absolute directives), especially when the evaluation of the site in question places it close to the edge of a treatment zone. Use of the nomographs will require professional judgment that should consider the factors that had the most bearing on assessing relative risk plus noting the presence of potential barrier plants[18]. Suggested treatments can be chosen with some flexibility allowing for professional judgment based on local experience. The closer your site is to one of the treatment zone edges the more likely it is that the treatment on the other side of the line could be used successfully.

An implicit assumption in these nomographs is that the order of treatment efficacy is:

a) root removal at or near harvest,
b) pop-up spacing, prior to latest free growing assessment, and then
c) alternative treatments as described in the Root Disease Management Guidebook.

In cases where previous harvesting, especially partial cutting systems, has occurred, or where frequent low intensity ground fires have been excluded, resulting in the overstocking of susceptible conifers, favour the more effective treatment.

The zones in the nomographs are labeled **I** for Intensive Treatments (**Id** Intensive deferred - pop-up spacing), **A** for Alternative Treatments and **M** for Minimal Treatments to match with the categories presented in the Root Disease Management Guidebook and the relative risk from the Risk Assessment Matrix.

In cases where two possible treatment intensities are indicated, the first one is preferred and the second one is to be used based on judgment of site-specific conditions as discussed below each nomograph.

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[18] Often shrubs that are poor hosts for DRA can be used as barriers to DRA between two or more otherwise susceptible trees in pop-up spacing operations (e.g. an alder bush separates an infected sapling from two other saplings that, due to proximity of the disease, would otherwise have to be removed).

2.25 General Description of Treatments

Intensive treatments (I and Id)

I - Intensive: Root removal, either by pushover logging or excavator stumping is considered the most effective treatment to reduce root disease impacts on high risk sites on suitable, less sensitive soils.

Id - Intensive deferred,(i.e., Pop-up Spacing) is suitable for lower risk sites or those with more sensitive soil conditions. The suitability of this option varies with species, Forest Floor Displacement Hazard, and Biogeoclimatic zone. While this is typically a stand management
activity, it can be prescribed in a Forest Development Plan or Silviculture Prescription for future disease control.

On moderate risk sites with less than 15 FFDH points, pop-up spacing would normally preferred because:

a) this treatment is more likely to work when there is less disease present, and,
b) pop-up spacing creates less counted disturbance than stump removal.

When pop-up spacing is prescribed in lieu of stump removal, the site should be re-examined prior to free-growing to determine if DRA expression actually warrants mechanical treatment. In conjunction with pop-up treatment, alternative treatments such as, planting more tolerant species or hand pulling as defined in the Root Disease Management Guidebook ought to be prescribed to further increase the probabilities of success.

A - Alternative Treatments

Alternative treatments, such as planting less susceptible species, are more likely to be successful on lower risk sites and are also promoted where soil sensitivities are high enough to preclude mechanical treatments.

M- Minimal disease treatment level (usually on *sites with a Low Risk Indicated*)

As per the guidebook, *"There are no restrictions on harvesting or regeneration strategies. However, unless Armillaria is completely absent from the stratum, **consideration should be given to prescribing for tolerant or moderately susceptible species."*** Such consideration is probably most important in the ICH and drier zones with previous harvesting.

Nomograph Zones

Nomograph zones with more than one treatment option designated are frequently indicated.

Id often appears with I, and A often appears with Id or M on the nomographs. In general the closer to the lower risk boundaries your site is, the more likely that the less aggressive treatment may be sufficient. Conversely, the closer to the maximum threshold your site is, the more likely it is that the more aggressive treatment will be the more effective option. In mid-zone, either treatment could be used, depending upon the direction provided and professional judgment that should consider root disease expression at time of harvest, local experience, and the potential for barrier plants to regenerate.

2.26 Stump and Coarse Woody Debris Management During Root Removal

The drier subzones in the Nelson Region have very little organic matter in the soil and forest floor. Historically, much of the forest floor material has been derived from rotting wood and stumps left after fire events. Organic matter is important for maintaining soil nutrients, moisture, and structure. In order to help sustain the level of organic matter in the soil, coarse woody debris (CWD) and stumps need to be maintained on these sites. Stumps should be retained on the following sites:

PP and IDF zones	- on all site series
MS, ESSF (dk, dc1), and ICH (xw, dw, mk1)	- mesic and drier site series

Stumps should not be treated as CWD - the need to leave CWD is in addition to the need to leave stumps. The current FPC Biodiversity Guidebook indicates the importance of maintaining CWD but also notes that utilization standards currently take precedent over leaving material on site - resolution in this conflict is anticipated soon. (Please note that post-logging debris can often meet volume requirements for CWD, as long as there is enough large pieces and the debris is distributed over the site.) Other recommendations in the Biodiversity Guidebook should be considered.

If excavator stump removal is utilized, stumps should be placed upside down back in their holes to ensure sufficient planting spots (do not pound them in). When pushover harvesting, a modified feller-buncher can drop stumps back in the hole quite effectively; otherwise, stage stump-bucking operations as close to the original stump holes as practical, to minimize the amount of extra traffic necessary to handle stumps.

2.27 Soil Disturbance Associated with Root Removal Treatments

Further direction on soil disturbance will be available following legislative changes. Some general direction is provided here:

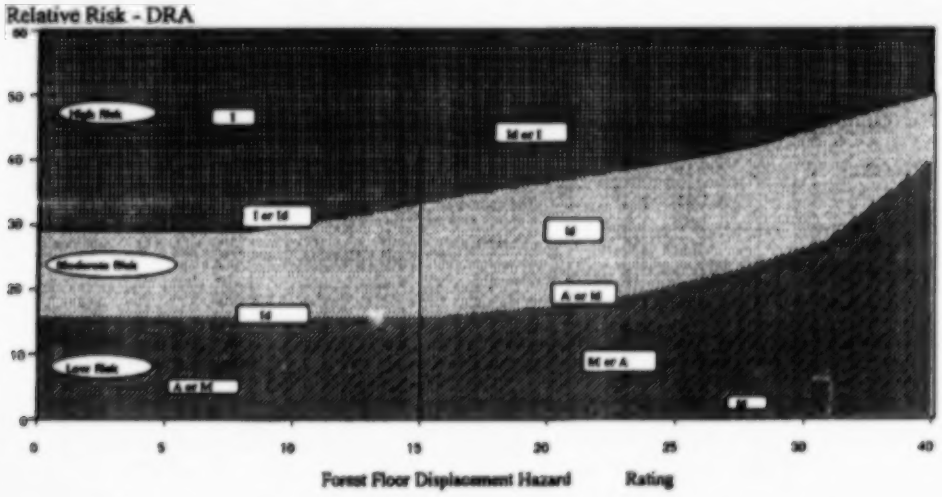
Both pushover logging and excavator stump removal have potential to create very large amounts of soil disturbance. Equipment operators need close supervision and should only be permitted to learn techniques on the least sensitive sites. Operating outside of the soil sensitivity criteria in Table 2 is strongly discouraged. All yarding disturbance should be confined to designated trails that should be rehabilitated afterwards to compensate for any extra disturbance associated with root removal.

Experience to date indicates that pop-up spacing normally causes considerably less disturbance and is therefore favoured over stump removal/pushover logging on more sensitive sites. Post harvest stumping, if done carefully with a proper excavator head, creates less disturbance than pushover logging.

3.0 NOMOGRAPHS

Three basic nomographs have been developed to correspond to the three "traditional" broad climatic zones; the wet belt, the dry belt and the subalpine zones.

Figure 2 Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region - ICH Wet Belt (ICHmw1, mw2, mw3, wk, vk1, wk1) (use ONLY if soil criteria met in Table 2)



I or Id delineates the area where circum harvesting root removal or pop-up spacing should be prescribed in the Silviculture Prescription. Generally, if your site plots in the Moderate risk zone, with < 15 FFDH points, prefer pop-up spacing and if > than Moderate risk, then prescribe a root removal treatment. Alternatively, if the risk is moderate or more and the FFDH > 15, then prescribe an alternative treatment at the lowest boundary, pop-up spacing at the mid levels of risk and stumping/pushover at the highest levels. However, a root removal treatment is preferred if FFDH is < 15 and:

- F, B or deciduous are the leading species;
- Lw, Py, Pw, Cw, or Hw are leading, and pre-harvest stocking of stems >7.5 cm. is >500 sph;
- if deciduous species are leading. Prefer pop-up spacing if: <500 sph, of stems >7.5cm;

Sites within the **Id or I** zone are suitable for pop-up spacing or root removal.

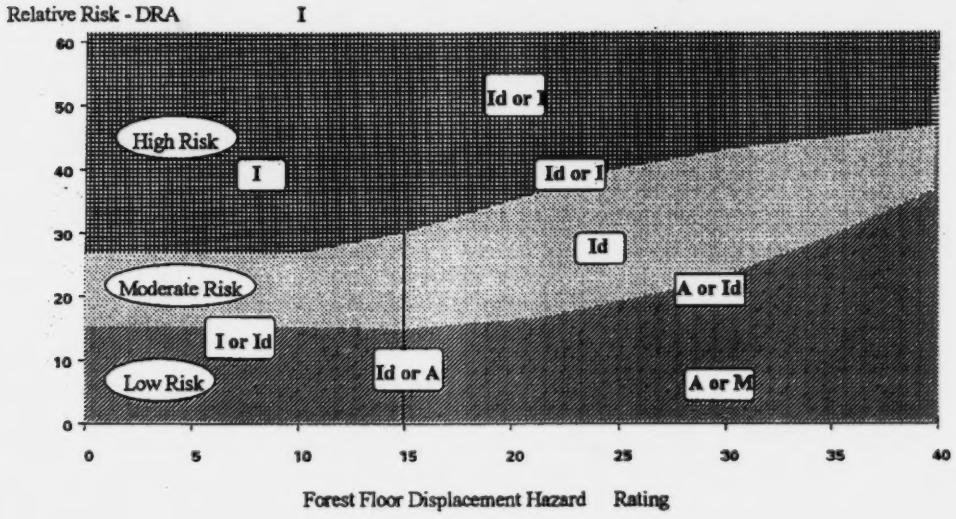
If stocking is > 1 000 sph, >7.5 cm. then root removal is indicated.
If stocking is < 1 000 sph, >7.5 cm., and

a) if the leading species is F, B, Pw, Lw, Pl, or Py then root removal is preferred but pop-up spacing is still an option, particularly if closer to the **Id** zone than the **I** zone;
b) if the leading species is Cw or Hw pop-up spacing is generally preferable following conventional logging but root removal is still an option, especially if the site plots closer to the root removal (I) boundary and if the stumps/root wads are not too large in terms of resulting disturbance. However if this is the case, it may be possible to only remove stumps < 50cm and then pop-up space later, if required[19].

Please note that Pl trees can suffer from a number of disease and insect problems that may indicate that other species would be more suitable for the site. If you find significant foliage disease has occurred over the past decade accompanied by short leader growth or excessive infection from stem rusts, infestations of pitch moth or root collar weevils then this could indicate that Pl should not be favoured in stand tending activities. Consult your local or Regional Forest Health specialists for advice.

[19] Generally, stumps of pines, Lw, Fd, B, S, and large deciduous are not as disruptive to the soils on site, especially in heavy infections. On these sites tree roots are often greatly reduced in size. Where trees, including Cw and Hw come out with "Q tip" roots rather than huge root wads, (this can be predicted from on site windthrow) then root removal can be conducted, other constraints permitting.

Figure 3 Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region - PP, IDF, MS, and ICHdw, xh, mk Biogeoclimatic Zones (use ONLY if soil criteria met in Table 2)



I or Id

Root removal is the preferred prescription:

- if F or B (grand fir) are leading species;
- if Lw, Py, or Pw are the leading species and the risk class is high or where pre-harvest densities exceed 1,500 sph > 7.5 cm DBH.

At FFDH >25, density should be >2,500 sph and > 7.5 cm DBH for root removal prescriptions.

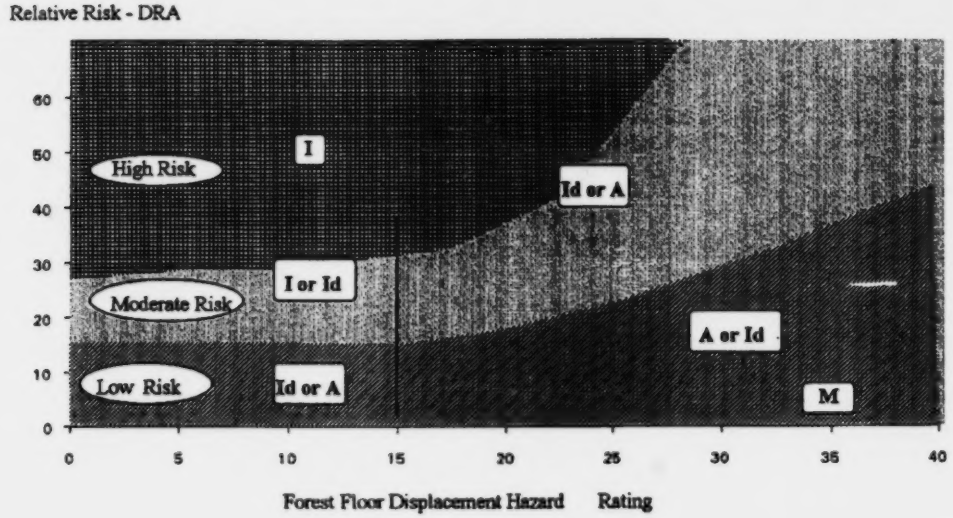
This treatment option is approached somewhat more aggressively since there is a greater probability of more susceptible trees being on site.

Id or I

Treat when required, but favour pop-up as the intensive treatment.

If Pl is the leading species, then root removal is preferred with high risk classes. At lower levels, use pop-up spacing or alternative treatments on dry sites.

Figure 4 Root Disease Treatment Recommendations for Armillaria Infected Stands; Nelson Forest Region: ESSF Biogeoclimatic Zone (use ONLY if soil criteria met in Table 2)



I or Id and Id or A (FFDH >15) - This zone is split at FFDH of 15. Below a FFDH of 15, pop-up is preferred since the technique is more effective than alternative treatments and disturbance is low. Above FFDH rating of 15, and at lower disease levels, alternative treatments are preferred, unless susceptible species are to be crop trees. DRA occurs in spotty small centres where visible symptomatic trees represent only a portion of the actual disease on the site. However, most of the below ground infection is in close proximity to the visible above ground infection. If the small centres are spaced widely, disease risk will usually be low. At higher levels of risk, root removal would generally be preferred. The upper portion of the **Id or A** (FFDH >15) boundary is preliminary because documented information is sparse; professional judgment will be required

A or Id - In this zone, mechanical treatments are less likely to be required and alternative treatments are more likely to be successful. However the closer your site plots towards the (Id or A) zone and the more susceptible the tree species prescribed, the more likely that pop-up may be needed. Conversely, the closer your site is to the **M** zone, the more likely it is that no treatment will be required.

I - This condition usually occurs as larger centres (> 1/2 ha) or within areas containing many centres (i.e., distribution is diffuse or approaching diffuse). Since other methods are much less likely to achieve disease control objectives, root removal is recommended to control DRA. (The ESSF is one of the only BEC zones where stratification can be used for DRA prescriptions.)

4.0 STAND MANAGEMENT PRESCRIPTIONS

Table 3, on the next page is to be used in Stand Management Prescriptions only.

Pop-up treatments for juvenile spacing is the recommended method where inoculum reduction is required in the **post free growing stage** of stand development. Pop-up treatments for commercial thinning have not been fully tested to date, but are probably going to be necessary, especially on those sites with obvious levels of root disease activity.

Pop-up treatments will do well in inoculum removal and in breaking root contacts at a crucial stage in the development of DRA in forest stands. Although pop-up treatments will cause considerably less site disturbance than root removal logging, there are similar constraints arising from the use of heavy machinery which may cause unacceptable soil disturbance, especially on some sites at some times of the year. Table 2 (an expanded version of Table 7 of the RDMGB 1995) is a guide to assessing the soil sensitivity of a site when considering mechanical treatments. Experience to date indicates that on deep snow (> 1-1.5m), pop-up spacing leaves little in the way of any soil disturbance

Because the productivity of a site can be adversely affected by excessive soil disturbance (e.g. soil compaction, erosion, mass wasting) as well as by root disease, the possible soil disturbance losses must be weighed against anticipated root disease losses. In setting recommended disturbance limits, the FPC Soil Conservation Guidebook focuses on the cumulative effects of displacement. The objective here is to optimize trade-offs between both major sources of potential impacts.

To optimize the cost effectiveness of pop-up treatments, especially early in stand development, other forest health/silviculture treatments can be effectively combined. Douglas-fir, Pl, and/or white pine pruning and canker excising, seeding, fertilizing, fill planting or brushing can easily be conducted in conjunction with pop-up spacing. If the risk points, **with** pop-up treatments, sum up to 25 points or less, the stand can be considered low risk for other stand treatments (unless, of course, all of the risk points are gained in the Disease Factors).

Under *Host Factors, (Species Mix)* and *Inoculum Potential*, it is possible to obtain (-) negative risk points. If these factors are negative risk pints, this will negate the hazards associated with both Site and Host Factors. If for some anomalous reason all the Disease Factors rate as High Risk, then consider the stand to be at high risk.

A pop-up treatment training manual is in progress and will be completed prior to the 1998 field season. Since this is a new treatment and requires the integration of many new and varied tasks for successful completion, only operators trained to conduct this treatment will be used on sites, receiving this treatment in the Nelson Forest Region .

Table 3 Armillaria Risk Assessment Matrix for Stand Management Prescriptions

RISK FACTORS[20]	RELATIVE RISK			
	Low	Moderate		High
Site Factors				
BEC Zone	PP (1)	IDF (2)	IDF (transitional), ESSF (>200m in elevation from the ICH) (3)	ICH, MS, ESSF,(<200m of elevation from the ICH (5)
Soil Moisture Regime	*Very Dry* (~ 120 days moisture deficit during growing season) in PP or IDF (i.e., subxeric or drier) or *Very Wet*, (excessive moisture during the growing season) in ICH, MS, or ESSF (i.e., hygric or wetter) (1)			All Others (3)
Host Factors				
Species mix (leading species only (based on Inventory label)	Lw, Py, & Ep, At, Ac (if < 40 years) (1)	Lw, Py, &/or Pl, S, Cw, Hw, Pw) or if Lw/Py/Pw is ≤ 19%[21] of spps mix (2)	Lw, Py &/or Pl, S, Cw, Hw, Pw with significant (>20%) levels of Fd /B (3)	**Fd, B and/or (if older than 40 Years)** Ep, At, Ac (5)
NB: If >2 conifers & each is ≥20% & 1 of the conifers is either Lw, Py or resistant Pw then rank as (-3)				
Species age	< 40 years species group 4 = (Ep, AT, Ac) (1)	> 20 years for species groups 2 = (Pl, S, Hw, Cw, Pw), 3 = (Py, Lw), or > 40 years for species group 4 = (Ep, At, Ac) (3)		<20 years species groups 2 & 3 or >60 years for group 4 spps; all ages (Fd/B) (5)
Species/Site suitability	"on site" as identified in Land Management Handbook # 20 (0)			Off - site (as per LMH #20) (3)
Inoculum Potential				
Inoculum size (@ root collar for trees < 15 cm DBH)[22]	small (<2.5cm.) (0) or if pop-up treated (-5)[23]	2.6 - 5.0cm (>1500 sph) (1)[24]	5.1 - 10 cm (>1000 sph) (3)	10.1 - 15cm (>500 sph) (4)	**large** (>15 cm DBH) & > 500 sph (5)
Disease Factors				
Incidence	none (0) scarce (1)	(2) ⇐ approaching	approaching ⇒ (3)	**High** (e.g. obvious) (5)
Distribution	none (0), scarce (1)	(2)⇐ small &/or scattered discrete centres	discrete centres increasing in size or number ⇒ (3)	diffuse (e.g. ubiquitous) (5)
Host species (being attacked)	none (0), scarce (1)	susceptible only (2)	susceptible & moderate (3)	all including resistant (5)
Stand layer (being attacked)	none (0), layer 4 (1)	if layer 4 's and 3's then score (2)		if layer 1, 2, and 3's attacked then (5)
Disease activity	none (0); if some greys (1)	if greys and reds (2)		**yellow-greens or/ yellows/reds** (5)
Pest Interaction	no (0)	no pest interaction = 0; if yes (e.g. any DM, DFx[25] or DSx but no DSB) (3)		yes (i.e. DSB) (5)
Point Totals	(-5) - +17	10 - 20		24

[20] Risk is defined as the probability of undesirable impacts resulting from conventional types of forest management treatments.

[21] But together are > 20%. If ≤ 19 % go to next higher risk category. In wet or moist ICH zones Pw can be considered ≡ to Lw in terms of DRA.

[22] As opposed to SP's, the population of stumps in SMP's can be either recently created or would be created by a proposed treatment; the risk points are estimates of "future stand" risk attributed to the non crop tree stumps left on site.

[23] Previous pushover logging or stumping of the original stand DOES NOT count; pop-up spacing done prior to a new entry Does count.

[24] If >1500 sph are cut & are >5cm at the root collar, then go to the next higher risk category; use upper limits to treat other categories similarly.

[25] DF = disease foliage and the "x" refers to any species affecting trees; DM = dwarf mistletoe; DS = stem diseases.

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(7) Province of B.C., 1995, Root Disease Management Guidebook, Forest Practices Code of BC.

(8) Province of B.C., 1995, Soil Conservation Guidebook, Forest Practices Code of BC.

Appendix I

Discussion of Risk Factors in the Risk Assessment Matrix

Modification and elaboration to the susceptibility ratings presented in the Root Disease Management Guidebook warrant consideration by the users of the Risk Assessment Matrix.

Armillaria Risk by BEC Zones (Revised)

Table A I-1 below, adjusts the BEC susceptibilities for the Nelson Forest Region (Appendix 3 in the Provincial guidebook) for the species groups in Table A I - 1.

Table A I - 1
Armillaria Susceptibility Risk by BEC and Tree Species Groups[26],[27]

BEC Zones⇒	PP	IDF	MS	ICH	ESSF
Tree Groups ⇓					
Group 1 (Fd, Bl Bg)	moderate/ high	moderate/ high	moderate/ high	high	moderate/ high
Group 2 (other conifers)	low	low/ moderate	low/ moderate	moderate/high	moderate/ low
Group 3 (Py, Lw)	low	low	low/ moderate	moderate	n/a
Group 4 (At, Ac, Ep)	n/a	low	low/ moderate	moderate/high	low/ moderate (?)

Recent Canadian Forest Service research found that DRA (Armillaria) was absent or if present, present in low amounts in either very wet or very dry site conditions. Both shedding slopes and permanent seepage sites appear to disadvantage DRA in drier ecosystems and wetter ecosystems, respectively. Using group 3 (Py or Lw) trees in dry areas and either group 4 or 2 trees in wetter areas would tend to decrease mortality. Pop-up spacing would reduce these impacts even further. CFS work involved using absolute moisture conditions for direct comparisons between zones which has been correlated with BEC moisture regime for field use.

In the ESSF, DRA tends to occur in centres that are more precisely marked by symptomatic trees. Root examinations showed that where no DRA was visible above ground, there was very little infection below ground. Hence some potential for stratification in regeneration exists where it does not in other BEC zones. Work is underway to see if the reduced DRA infections in the drier zones is attributable to the zones themselves or to the tree species. In some cases, Pl seems to get infected early, die quickly but does not pass the infection on to its neighbours. Work in the summer of 1997 (to be published in 1998), by the Canadian Forest Service, investigated whether Fd behaves the same manner in the dry zone.

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[26] This table replaces the table in 9.3 in RDMBC, for the Nelson Forest Region.

[27] Species that are off-site (or even "somewhat" off-site) will likely be more susceptible to Armillaria. Other insect and disease problems will probably interact with Armillaria for an even larger impact on forest health.

Host Susceptibility

The species susceptibility tables in the Root Disease Management Guidebook classify spruce as susceptible. Evidence and experience within the NFR suggests that this species should be classed as moderate and is so reflected in Table I-2, below by its placement in group 2. Pw is transitional to moderate/resistant and **only blister rust resistant material** may be included in the Py and Lw group in the moister/wet ICH zone.

Susceptibility to DRA infection can be viewed from at least several aspects. Table I-2 lists the species groups by two types of susceptibility characteristics. Each of these can be influenced by position on the slope and its relationship to moisture levels, by Biogeoclimatic zones (presumably through enhancing the host vigour and inhibition of DRA rhizomorphs) and by position of trees in relation to active inoculum. Few trees can resist a full blown spreading infection as is often found in centers where eventual infection is more of a function of inoculum levels and time than it is of susceptibility/resistance of individual tree species. The table below is meant to reflect: a) a background level of root disease and **not** of highly active centers; and b) where the DRA infection is found on distal roots. Infections occurring at the root collar favours DRA and those infections are usually fatal. As well, differences in the ability to prevent infection from spreading have been observed among host species (DRA virulence has not been tested yet). When Dr. Morrison publishes his manuscript, we may be able to replace susceptibility, tolerance and resistant with actual proportions of trees that could be expected to die.

Conventional treatments, those that leave tree roots in the ground, will invalidate to a certain (large ?) extent, the comments contained within the table.

Table A 1 - 2
Host Susceptibility To Armillaria in the Nelson Forest Region

Species	Susceptibility to Killing[28]			Tolerance to Infection		
	(related to a species ability to exfoliate attempted infections by bark hypertrophy - rapid bark growth below a DRA invasion)			(related to resisting DRA movement up the roots via one or more of: 1) the formation of callus tissue around the "killing zone"); 2) formation of adventitious roots from callus; or 3) resin soaking of xylem). Position of infection at the root collar offers advantage to DRA.		
	< 20 years	20 - 60 years	> 60 years	< 20 years	≥ 20 years	
Group 1						
Fd	S	S	S	S (tolerance is low and easily killed)	Ability to stop infection increases with age until ≈ 80 - 100 yrs when most trees fail	
B (as a group)	S	S	S	S (tolerance is low and easily killed)	As above	
Group 2						
Pl	S	T	S	R (resists disease vigorously)	DRA and IBM are related but IBM or fire cause mass mortality	
Hw	S	T	T	S	T (tolerates DRA but struggles)	
Cw	S	T	T	S	T	
S	S	T	T/R ?[29]	T	T	
Pw[30]	S	T	T/R ?	R	R	
Group 3						
Py	S	T	R	R	R	
Lw	S	T	R	R	R	
Group 4						
Ep	R	T	T/S	R	T	S when >60 yrs.
At/Ac	R	R/T	T/S	R	T	S when >60 yrs.

(Note S, R and T are defined as follows: **S** = susceptible to being infected and has a low tolerance to infection; **R** = resists infection vigorously and successfully most of the time and will overgrow DRA lesions if left undisturbed; if disturbed by conventional spacing this category of trees will either die quickly or re-contain the lesions but rarely struggles along with infections over long periods of time successfully; **T** = susceptibility to infection decreases with age unless significantly affected by other conditions and then will struggle with disease over long periods of time; significant effects of growth loss over time; small lesions may be overgrown. Trees tend to suffer early mortality but if not killed outright then they are tolerant to infection. If disturbed by conventional spacing or thinning these trees will tend to die but some will continue the struggle.)

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[28] Infection is defined as the invading fungus beginning to kill living cambial tissue; presence of DRA in the bark alone is not considered an infection.

[29] Spruce tap roots have been observed with DRA infection and the disease was compartmentalized by the laterals. DRA then becomes an encapsulated butt decay.

[30] Only provided that no white pine blister rust is present. If present, Pw becomes a problem tree for both DSB and DRA.

Appendix II

Discussion of the Role of Armillaria Root Disease Surveys

Tree-based and area-based root disease surveys have been prescribed as methods of estimating the incidence and probable impact of Armillaria root disease. Certain characteristics of root diseases, and Armillaria especially, call into question the usefulness of these survey methods in assessing risk.

Assumptions About Surveys

Simply put, in most forest health surveys we look for signs and symptoms of disease and use quantitative and/or qualitative data to make an evaluation of impact. The most fundamental assumption in this simple model is that all the signs and symptoms of infection will be detectable above the ground. There is, of course, a time element involved (i.e. the incubation period between the time of infection and the time when symptoms will be evident). This time period can vary from weeks (needle cast) to years (root disease).

Problems/limitations With a Tree-based Survey

A tree-based, above-ground survey can tell us what proportion of the trees are exhibiting symptoms or signs of infection and disease. Such a survey cannot tell us what proportion of trees are infected but not yet exhibiting symptoms. Because of the time lag between infection and appearance of disease symptoms, it would be an extremely rare case where all instances of infection could be detected by a non-destructive, above-ground survey. The problem, then, is what proportion of the infection has remained undetected, and therefore, what is the true infection level? To date, no survey method has been devised that can provide this information, nor has a consistent ratio of detected to undetected infection been observed

Problems/limitations With an Area-based Survey

Area-based surveys have a certain appeal, for as well as presenting stand attributes in terms of stems/ha, foresters are familiar with thinking of proportion of areas, but usually on a different scale of resolution (e.g. on a landscape level). One appeal of area-based surveys is that area units can be evaluated simply and quickly for presence/absence of an attribute. However, there is a fundamental problem associated with this method, the size of the area unit/pixel used to assign the presence/absence of the attribute. For example, would it mean the same thing, if surveying to quantify the presence/absence of a micro-organism in a stand, to use a 1 ha survey unit as it would to use a 1 cm^2 survey unit and to extrapolate each to a stand level? Intuitively, it is apparent that size of the area unit is important but setting the size limits is difficult. It has to do with the size of the area which is influenced by the organism - its "zone of influence". How many m^2 does a root-disease infected tree influence, and what does this really mean in terms of conveying information about the condition or future of the stand? Does the size of tree matter? Does the stand density matter? Although methods of measuring zone of influence have been developed for inter-tree competition, no such zone of influence has yet been determined for root disease.[31]

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[31] Within 5.65m radius of an infected tree that is showing above ground signs and symptoms, in the moist/wet zones there seems to be a fairly consistent proportion of trees that are infected but not yet showing above ground symptoms at about twice the level found in non symptomatic stands.

Appendix III

Armillaria Risk vs. Treatment Risk: Interpretation of Likely Outcomes and Probable Impacts

These tables, that list DRA risk by treatment types (options), likely outcomes and probable impacts, were created to aid prescribers in developing an understanding of the effects DRA can have on various objectives. For objectives where impacts from Armillaria root disease, are either irrelevant or desirable it is still important to recognize that there can be effects. For example, these objectives could include;

* situations where timber or recreational values[32] are fourth or lower in management objectives priority
* creation of wildlife trees or specialized habitat for particular wildlife species such as raptors or squirrels, or
* creation of viewscapes where structural and species diversity are important to form a mosaic of colours, texture, and/or temporal features.

The template outlined below shows the overall outline and organization of the tables presented over the next few pages. It is important to note that a serious attempt was made to be "bias" neutral when developing the details contained within the outcomes and probable impact tables.

Armillaria Risk vs. Treatment Risk Template

Armillaria Risk[33]	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
High	Conventional (= minimal)			
High	Alternative			
High	Intensive (or intensive delivered)			
Medium	Conventional (= minimal)			
Medium	Alternative			
Medium	Intensive (or intensive delivered)			
Low	Conventional (= minimal)			
Low	Alternative			
Low	Intensive (or intensive delivered)			

[32] Where recreational opportunities are provided to attract or invite the use of Crown Land, root disease would not have much impact on low density and dispersed - use activities but would be significant for recreational values such as, campsites and viewpoints where public safety (and liability) are important issues.

[33] Risk is defined as the probability of impacts resulting from conventional types of forest management treatments. These impacts may be either undesirable or desirable depending upon management objectives.

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
High	Minimal (=Conventional)	**Leaving cut stumps in the ground = inoculum creation:** - conventional harvesting, any silviculture system - conventional stand tending treatments - manual brushing **Stand establishment with no regard for root disease:** - planting group 1 or 2 ** tree species, especially if using stumps for sheltering seedlings **Stand management with no regard for root disease:** - conventional juvenile spacing or commercial thinning ** see Appendix I, Table I-1 for species groups	High probability of: * ongoing mortality * small stem size and usually moderate to severe growth impediment of all species increased windthrow, snow or ice press * increased insect activity * very irregular stand structure * species diversity (?)[34] * ungulate forage species can be of generally poorer quality and size if present at all (e.g., red stemmed ceanothus); other species such as Douglas maple or red osier dogwood appear to be unaffected. * after juvenile spacing there may be a flush of DRA caused mortality; if so the disease may continue to cause mortality or the trees may compartmentalize the disease. Depending upon tree species, the reappearance of DRA could occur anytime after 80 years from time of treatment; * after commercial thinning, expect some DRA to flush and show up in the residual trees	Pros - best chance of creating snags for wildlife trees - some ungulate forage species may increase in productivity Cons - least productivity from timber, and possibly from the ungulate point of view if forage species are susceptible - most unsafe for stationary recreation activities (e.g., camping, viewpoints) - least predictable over the long term and - most likely to lead to other insect and disease problems - most likely to create severe forest fire hazards and to elevate low intensity ecosystem burns to the dangerous catastrophic stand replacement fires

[34] DRA has a wide host range which includes many shrubs (many of which are quite susceptible), herbs and forbes. DRA's effect on species diversity is largely unknown as are the secondary effects on animal populations. DRA's effect on structural diversity is known to benefit animals that require wildlife trees but it is suspected that there may be detrimental effects on ungulate winter and early spring food supplies, especially when they consist of susceptible shrubs.

	Treatment Types	Treatment Descriptions	Likely Outcomes	Probable Impacts
High	Alternative	**Leaving cut stumps in the ground = inoculum creation but modified to induce conditions less suitable for DRA:** - conventional clearcutting and slash burning (e.g., Rhizina root disease is enhanced by fire and if triggered it may prevent DRA flushing after conventional logging) planting group 3 or 4 seedlings (less susceptible species) - avoiding inoculum (planting away from stumps, defer conifer regeneration) - use of barrier shrubs/trees (if left) - conifer fallow (e.g. avoid growing trees, particularly conifers, and replace with non host crop material such as grass) In stand management: - favour lower risk species in juvenile spacing - leave barrier shrubs and deciduous trees - grow C, H at high densities (moist/wet sites) or - grow Lw, Py at reduced densities (away from stumps) on dry sites - early spacing and/or brushing (dia. @ root collar < 5 cm) **Experimental** - manual spot treatments - cut to leave live bottom whorl (dry sites only & never with C or H) and allow crop to go to full crown closure to shade these stems out (if not the cut stems will produce multiple leaders if allowed to grow) - space with selective herbicide treatment	Moderate to high probability of * ongoing mortality * small stem size and usually moderate to severe growth impediment of group 1 & 2 trees and moderate to high growth impacts on group 3&4 trees * increased windthrow, snow or ice press * increased insect activity * irregular stand structure * effect on species diversity (?) ungulate forage species may be of generally poorer quality and size (especially if red stemmed ceanothus) * after juvenile spacing there will likely be a flush of DRA caused mortality; if so the disease may continue to cause mortality or the trees may compartmentalize the disease. Depending upon tree species, the reappearance of DRA could occur anytime 50 - 80 years after treatment (growth reductions have been recorded beginning at 40 years of age); * after commercial thinning, expect some DRA to flush and show up in the residual trees	Pros and Cons: - as above but with lesser or similar severity

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Probable Impacts
High	Intensive	**Inoculum removal** (both at harvesting and stand tending stage) - use of barrier shrubs and trees (if root removed later during pop-up spacing) - conifer fallow (e.g. grass)	good probability of reducing tree mortality, growth reduction and reduced likelihood of the undesirable interactions mentioned above plus improved growth and quality of ungulate forage production.	Pros - most likely to provide the largest gains in forest productivity for the least overall cost; reverse of the "cons" above Cons -soil disturbance may be counterproductive without careful planning.

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
Moderate	Minimal (=Conventional)	**Leaving cut stumps in the ground = inoculum creation:** - conventional harvesting, any silviculture system - conventional stand tending treatments - manual brushing **Stand establishment with no regard for root disease:** - planting group 1 or 2 tree species, especially if using stumps for sheltering seedlings **Not conducting forest health stand tending programs** - Not treating Pw for white pine blister rust leads to the creation of large highly - infectious inoculum when the Pw die due to rust infection.	Moderate probability of * ongoing mortality * small stem size and growth impediment of group 3 & 4 trees * increased windthrow, snow or ice press * increased insect activity near rotation end * somewhat irregular stand structure * effect on species diversity (?) * ungulate forage species can be of generally poorer quality and size if present at all (e.g. red stemmed ceanothus); other species such as Douglas maple or red osier dogwood appear to be unaffected.	Pros - usually least costly option Cons - high risk activities provide a second chance for DRA to become intensified and brought up to a high risk class. - by the time the failure of management objectives are evident, remedial treatment costs are the highest and most difficult to justify

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
Moderate	Alternative	**Leaving cut stumps in the ground = inoculum creation but modified practices to induce conditions less suitable for DRA:** - conventional clearcutting and slash burning (e.g., Rhizina root disease is enhanced by fire and if triggered it may prevent DRA flushing after conventional logging) **Stand Establishment** - planting group 3 or 4 seedlings (alternate spps) - avoiding inoculum (planting away from stumps, defer conifer regeneration) - use of barrier shrubs/trees (if left) - conifer fallow (e.g. grass) **Stand Tending** - Favour less susceptible species - grow C, H at high densities (moist/wet sites) or - grow Lw, Py at reduced densities (away from stumps) on dry sites - early spacing and/or brushing (dia. @ root collar < 5 cm) **Experimental** - manual spot treatments - cut to leave live bottom whorl (dry sites only & never with C or H) and allow full crown closure to eventually shade those cut stems out (otherwise they will produced multiple topped trees - space with herbicides	Moderate to high probability of: * ongoing mortality * small stem size and severe growth impediment of group 1 & 2 trees and moderate to high growth impacts on group 3 & 4 trees * increased windthrow or snow/ice press * increased insect activity * very irregular stand structure * effect on species diversity (?) * ungulate forage species (?) * after juvenile spacing there may be a flush of DRA caused mortality; if so the disease may continue to cause mortality or the trees may compartmentalize the disease. Depending upon tree species, the reappearance of DRA could occur anytime 50 - 80 years after treatment (growth reductions have been recorded beginning at 40 years of age); * after commercial thinning, expect some DRA to flush and show up in the residual trees	Pros - most palatable to forest managers due to perceived low cost and acceptability to "non-timber" interests - reasonable probability of maintaining status quo for productivity ("reasonable" probability is our best guess based on our current understanding) Cons - maintaining status quo of productivity may well mean the perpetual loss of one or two site classes (e.g. if productivity has been reduced from good to poor due to DRA's response to previous management activity, this is the loss that may well be perpetuated)

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
Moderate	Intensive	**Inoculum removal** (both at harvesting and stand tending stage) - use of barrier shrubs and trees (if root removed later during pop-up spacing) - conifer fallow (site prep followed by legume or grass seeding) - early hand-pulling	Significantly reduced probability of: * ongoing mortality * small stem size and growth impediment of all groups of trees * windthrow snow/ice press * insect activity near rotation end * developing irregular stand structure * effect on species diversity (?) * ungulate forage species can be of generally poorer quality and size if present at all (e.g. red stemmed ceanothus); other species such as Douglas maple or red osier dogwood appear to be unaffected.	Pros - best chance to maintain/increase forest productivity - DRA - created Wildlife trees could be kept but would not be replaced as stand progresses through the rotation Cons - -soil disturbance may be counterproductive without careful planning.

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
Low	Minimal (=Conventional)	As per above high risk treatments	A somewhat increased probability of: * ongoing mortality * growth impediment of all tree groups * windthrow * snow or ice press * insect activity near rotation end * irregular stand structure * species diversity (?) * ungulate forage species (?)	Pros - Low risk areas can be treated with low cost but high risk treatments with a good chance of remedial action success if caught early Cons - Armillaria's propensity to build up inoculum even from low levels requires a full rotation monitoring plan
Low	Alternative	As per above medium risk treatments	Reduced probability of * ongoing mortality * small stem size and growth impediment of trees, even less impacts on group 3 & 4 trees * windthrow * snow or ice press * insect activity * irregular stand structure * effect on species diversity (?) * decreasing of some ungulate forage species quality and size (e.g. red stemmed ceanothus); red osier dogwood and Douglas maple essentially unaffected	Pros - better than even odds of maintaining forest productivity but Cons - poor or no chance of improving forest productivity - Armillaria's propensity to build up inoculum even from low levels requires a full rotation monitoring plan - somewhat more costly

DRA Risk	Treatment Types	Treatment Descriptions	Likely Outcomes	Interpretation (of Probable Impacts)
Low	Intensive	As per above low risk treatments	Lowest probability of * ongoing mortality * small stem size and growth impediment of all groups trees * windthrow * snow or ice press * insect activity near rotation end * developing irregular stand structure * effect on species diversity (?) * ungulate forage species generally of best quality and size and if present, usually in larger clumps (e.g. red stemmed ceanothus)	Pros - stands have the maximum flexibility for most management objectives - ungulates usually have optimal conditions in most situations; in dry ecosystems, frequent ground fires will lead to very good multiple use conditions - very best chance to maintain forest productivity Cons - requires specific forest management activities to optimize timber and wildlife values - stands manipulated for human desired "products" will adversely affect those species requiring open stands, large dead snags - cost is probably not justifiable - -soil disturbance may be counterproductive without careful planning. as a result; risk would not be justifiable

Appendix IV

Application Example:

Silviculture Prescription

Example A

BEC: ICHdw-01; FdPl 530 - M; signs of some very old stumps (60+ years) but unable to determine silviculture system used; DRA is patchy with a few small centres scattered through out the block (mostly grays and a few reds) but IBM is occurring through out the type at a red:green ratio of 3:1; the trees are 27m tall with DBH range of 20 - 45 cm and a volume of 267 m3/ha.

Using the Armillaria Risk Assessment Matrix, this stand would score 5 for ICH, 3 for soil moisture regime, 5 for species mix (Fd is leading), 1 for species age (age class 5 is less than 100 years), 0 for species/site suitability (both species are primary or secondary); 0 for previous management since the length of time and inability to tell which silviculture system was used; 2 for disease incidence; 2 for discrete centres; 3 for hosts being attacked; 5 for stand layer being attacked; 2 for disease activity; and 5 for pest interaction (IBM and DRA interactions have been described in the literature and seen in the field).

Thus the total score is 33, a high future stand risk to DRA.

This stand is solidly into the high risk category. Given the ratio of red to green attack from IBM, this would likely be the end of an initial epidemic attack that could enhance DRA activity. Most of the indicators (7 of 12) are on the high side of the risk table in a BEC zone known for DRA activity. Given a go on site sensitivities this stand should undergo an intensive treatment.

Example B

BEC: ICDmw2-04; FdCwHw(SwPw) 110-M; stumps of Fd, Cw, Hw, in a clear-cut; DRA is patchy in one to 3 tree centres, with a mix of reds, grays and yellows of all species with about 20 spots per ha more or less evenly scattered; occasional layer 2 trees (residuals) but mostly layer 3 and some layer 4 trees are infected; about 15% of the Pw are either dead or with stem cankers. This stand is being assessed for free growing. The previous stand had pixel survey indicating 7% of the pixels were infected, but while the stand was within parameters for stumping or pushover logging, the stand was not treated for DRA.

This stand would be assessed using the Silviculture Prescription Armillaria Risk Assessment Matrix. It would score 5 for ecosystem, 3 for moisture regime, 5 for species mix, 1 for species age, and 0 for site suitability. Previous logging would score

3 for clear-cut Disease factors would score 5 for high incidence, 5 for diffuse, 5 for species being attacked (all species are highly susceptible when < 20 years old), 5 for yellows and reds, and 5 for pest interaction (Pw with DSB - white pine blister rust). This young stand thus totals 42 risk points, well above the 23 points required of free growing stands. In order to become free growing this stand could be treated with a pop-up technique or as a last resort, stumped and rehabilitated. If a pop-up treatment were conducted, wait at least two full growing seasons before reassessment for free growing. If that time period exceeds the latest free growing deadline, the amendment to the SP must be submitted and approved prior to the expiration of the deadline.

Stand Management Prescription

BEC: IDFdm1-01; Pl Lw Fd 110 - M; signs of some very old stumps (60+ years) in an old clear cut; DRA is patchy with a few small centres and individual trees attacked, scattered through out the block (mostly layer 4 grays with a few reds and yellows in layer 3) but DSG is occurring through out the type; the trees are 1.0 to 2.7m tall with DBH range of 0 - 4.5 cm., 5800 sph and a volume of 26.7 m3/ha in Fd vets.

The site scores 2 for BEC, 3 for soil moisture, 3 for species mix; 5 for species age; 0 for "on-site"; the volume in Fd vets would suggest about 30-50 trees per ha > 17.5 cm with > 1500 small stems in the < 2.5 - 5.0 cm range would score 3; 3 for incidence; 5 for distribution; 3 for hosts being attacked; 2 for layer being attacked; 5 for disease activity; 3 for pest interaction.

Thus the total score would be 37; a high future risk stand. This stand ought to be treated with a pop-up technique, probably in another five years when disease activity is more obvious and trees are somewhat larger. If not pop-up treated, this stand would be of too high a risk to invest intensive management dollars.

Feel free to contact the Regional Pathologist for any circumstances that are not covered or that you feel are unusual. Risk rating details can usually be worked out over the telephone; if not a field trip may be required.